REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
08-06-2010

2. REPORT TYPE
CONFERENCE PROCEEDING

3. DATES COVERED *(From - To)*
2010-2010

4. TITLE AND SUBTITLE
In Situ Metrology for the Corrective Polishing of Replicating Mandrels

5a. CONTRACT NUMBER
NNX10CD72P

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Dan Thompson, Dave Youden, John Kelchner

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Zeeko Technologies, LLC
3495 KENT AVE STE K100
WEST LAFAYETTE, IN 47906

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
NASA Goddard Space Flight Center

10. SPONSOR/MONITOR'S ACRONYM(S)
NASA GSFC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Presented at Mirror Technology Days, Boulder, Colorado, USA, 7-9 June 2010.

14. ABSTRACT
The International X-ray Observatory (IXO) will require mandrel metrology with extremely tight tolerances on mirrors with up to 1.6 meter radii. Metrology on these shapes using conventional interferometry is difficult. A system that could perform in-situ metrology on the polishers may be ideal. Error budgets for the IXO mirror segments are presented. A potential solution is presented that uses a voice-coil controlled gauging head, air bearings, novel probes, and temperature control.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR	17	Hans-Peter Dumm

19b. TELEPHONE NUMBER *(include area code)*
505-853-8397

In Situ Metrology for the Corrective Polishing of Replicating Mandrels

NASA Phase I Contract NNX10CD72P

Dan Thompson
Dave Youden
John Kelchner
Zeeko Technologies, LLC

Mirror Technology SBIR/STTR Workshop
Boulder, CO
June 8, 2010

The Challenge: Develop an instrument for the process-intermittent metrology of the IXO mandrels to control the corrective polishing process

- Extremely tight tolerances
- Very large radii (to 1.6 m)
- Unsuitable for interferometry
- Radii too large for on-center polishing or metrology
- Ultimate need to provide in-situ metrology on the polisher(s) for rapid process control

Our solution: Develop a dedicated metrology instrument using a “virtual axis of rotation”

Mandrel Sizes for IXO

	Inner Ring	Middle Ring	Outer Ring
Azimuthal Span of Each Module (degrees)	30	15	15
Number of mandrels	286	230	206
Radius of Each Module	372-693 mm	740-1110 mm	1156-1605 mm
Polished chord width of Slab Mandrels	255-475 mm	310-470 mm	500-700mm
Clear Aperture length	200 mm	200 mm	200 mm
Mandrel polished length	275 mm	275 mm	275 mm

Error budget for individual forming mandrels for IXO

Mandrel Surface Parameters		Error Allocation for either Primary or Secondary (assuming perfection for the other)		RSS Contribution to HPD (arcsec)	Cumulative HPD (arcsec)
		Numerical Value	Unit		
Radius	Average Radius	10.00	μm	0.2	0.2
	Radius Vatiaion	0.20	μm	0.1	0.2
Cone Angle	Average Cone Angle	0.50	arcsec	0.7	0.8
	Cone Angle Variation	0.40	arcsec	0.7	1.0
Axial Sag	Average Sag	0.05	μm	0.5	1.1
	Sag Variation	0.05	μm	0.2	1.1
Axial Figure	Low Frequency Figure (200mm-20mm)	5.00	nm	0.4	1.2
	Mid Frequency Figure (20mm-2mm)	2.00	nm	0.9	1.5
	High Frequency Figure (2mm-0.002mm)	NA	nm	NA	1.5

A 3 Phase Approach:

- Phase 1: Develop a conceptual design
- Phase 2: Develop a stand-alone metrology system
- Phase 3: Integrate the metrology and manufacturing systems

Phase 1 Work Plan

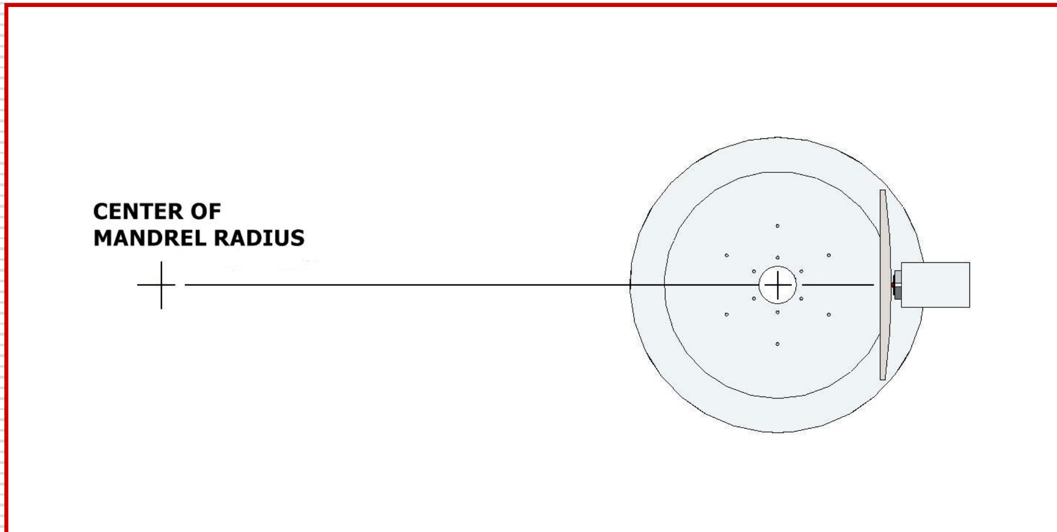
- Establish a detailed specification for the instrument
- Develop a conceptual design for metrology equipment
- Create an error budget for metrology equipment
- Develop a plan to combine polishing and metrology equipment
- Prepare a final report and a project plan for Phase 2 of the SBIR

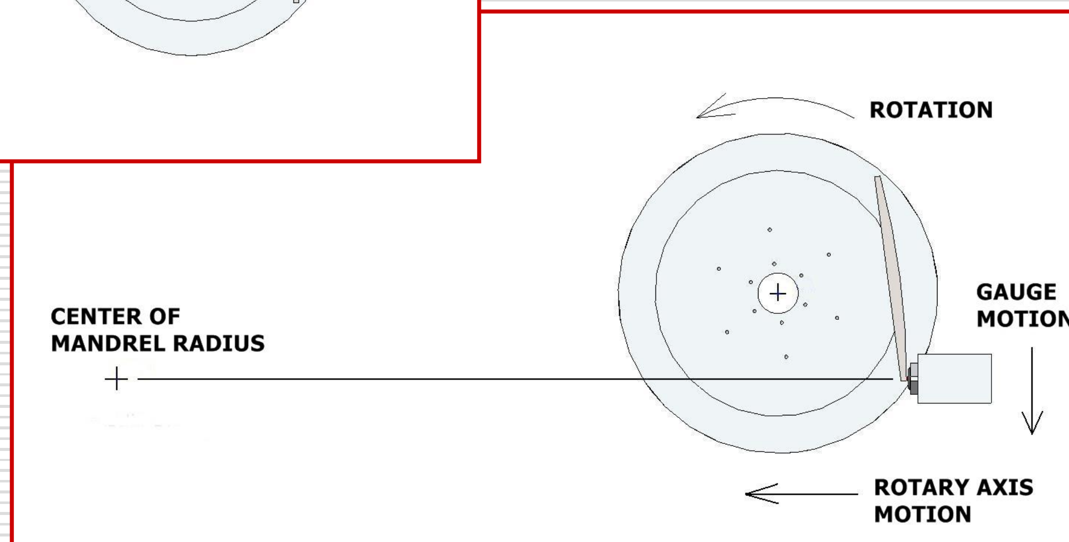
Zeeko IRP 400

Key Technologies and Principals

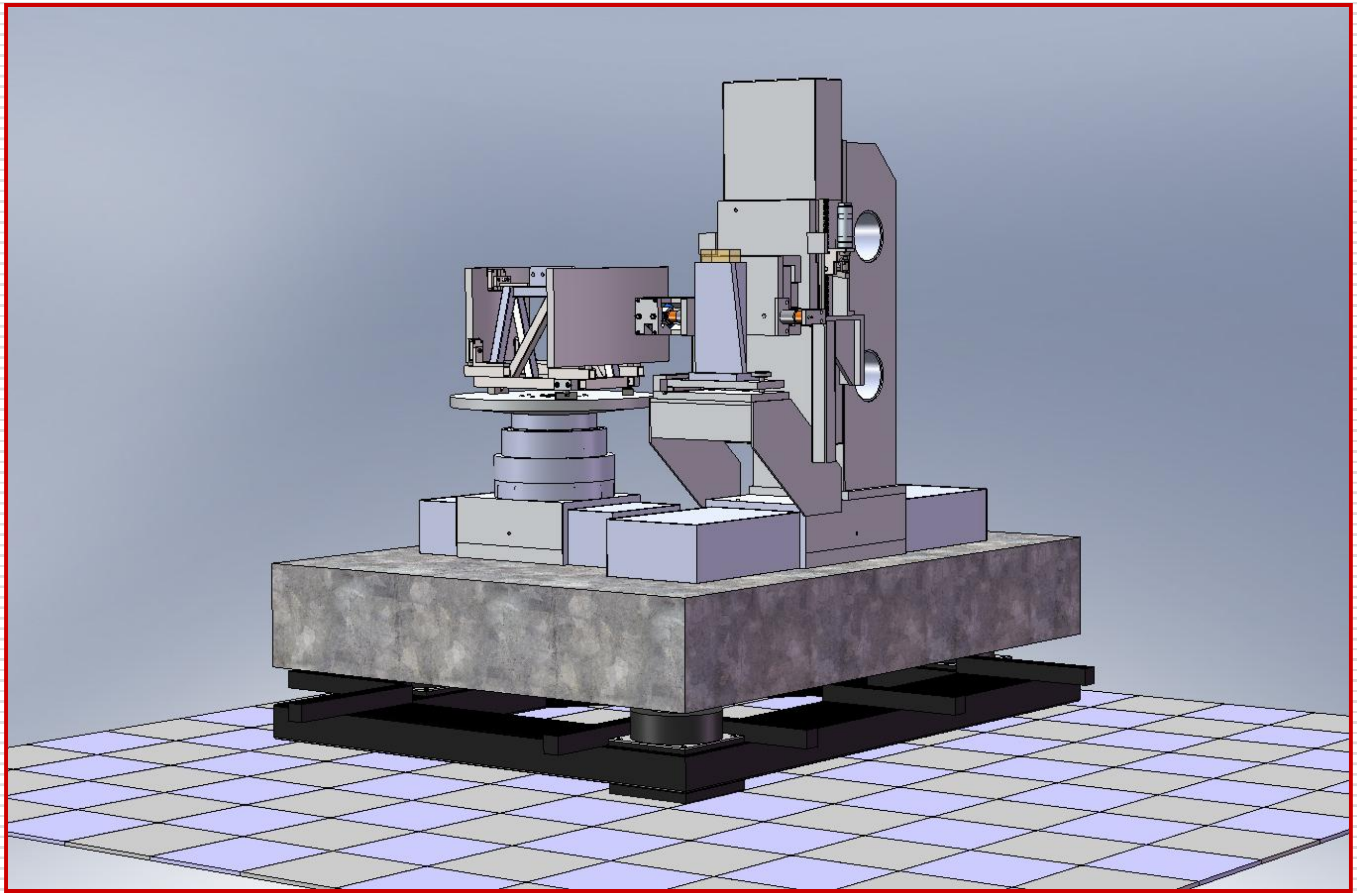
- Extensive use of error budgeting as a design guidance tool
- The development of a novel contact voice-coil controlled gauging head, with dynamic range, resolution and uncertainty necessary to meet component metrology requirements
- The merging of an array of precision engineering principles and design elements including air-bearing components, a novel probe design, temperature control in a radical environment, and the integration of all of these technologies on a computer controlled machine to control the manufacturing process

How it Works

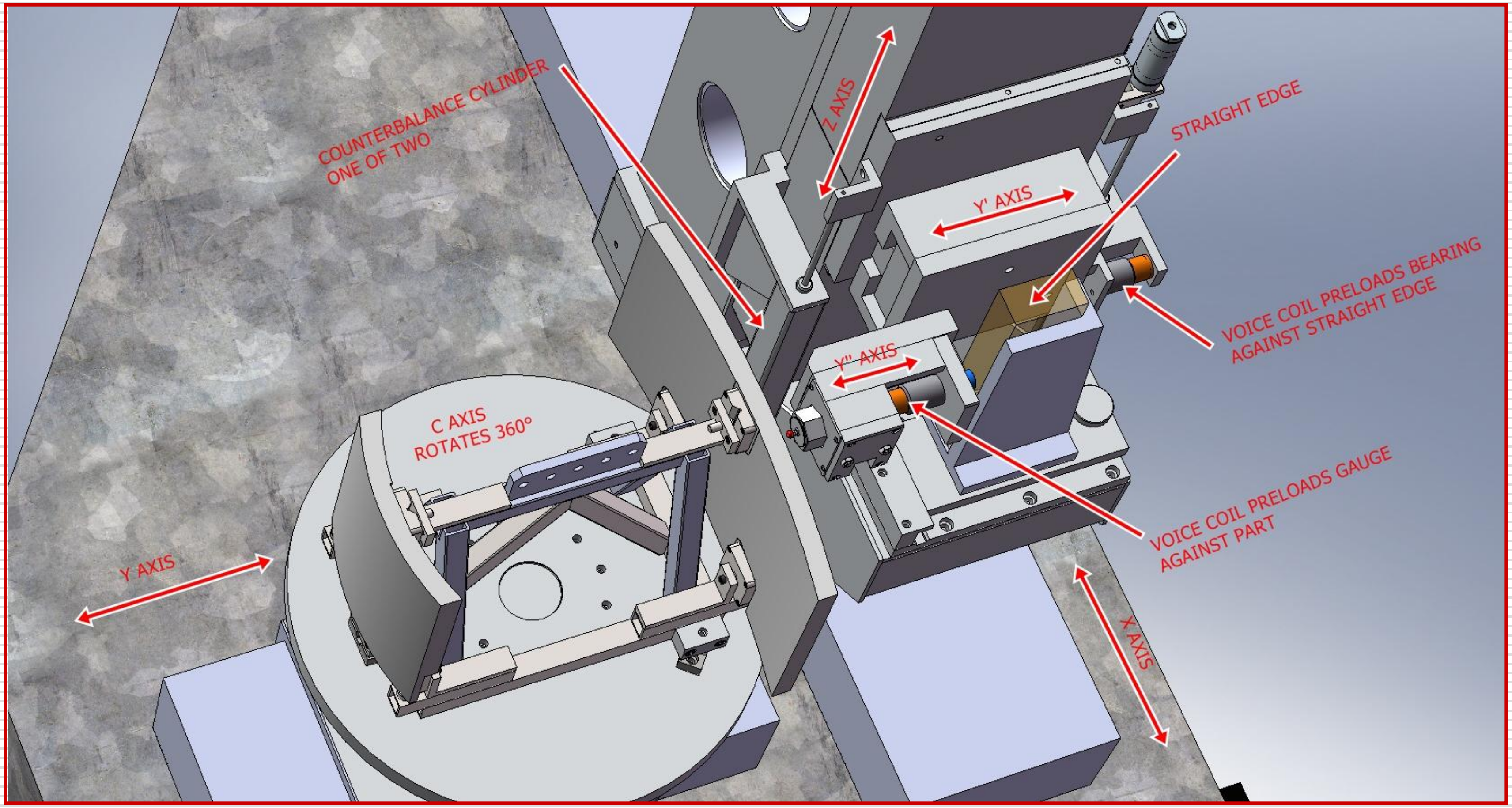

CENTER OF
MANDREL RADIUS


ROTATION
CENTER OF
MANDREL RADIUS
GAUGE
MOTION
ROTARY AXIS
MOTION

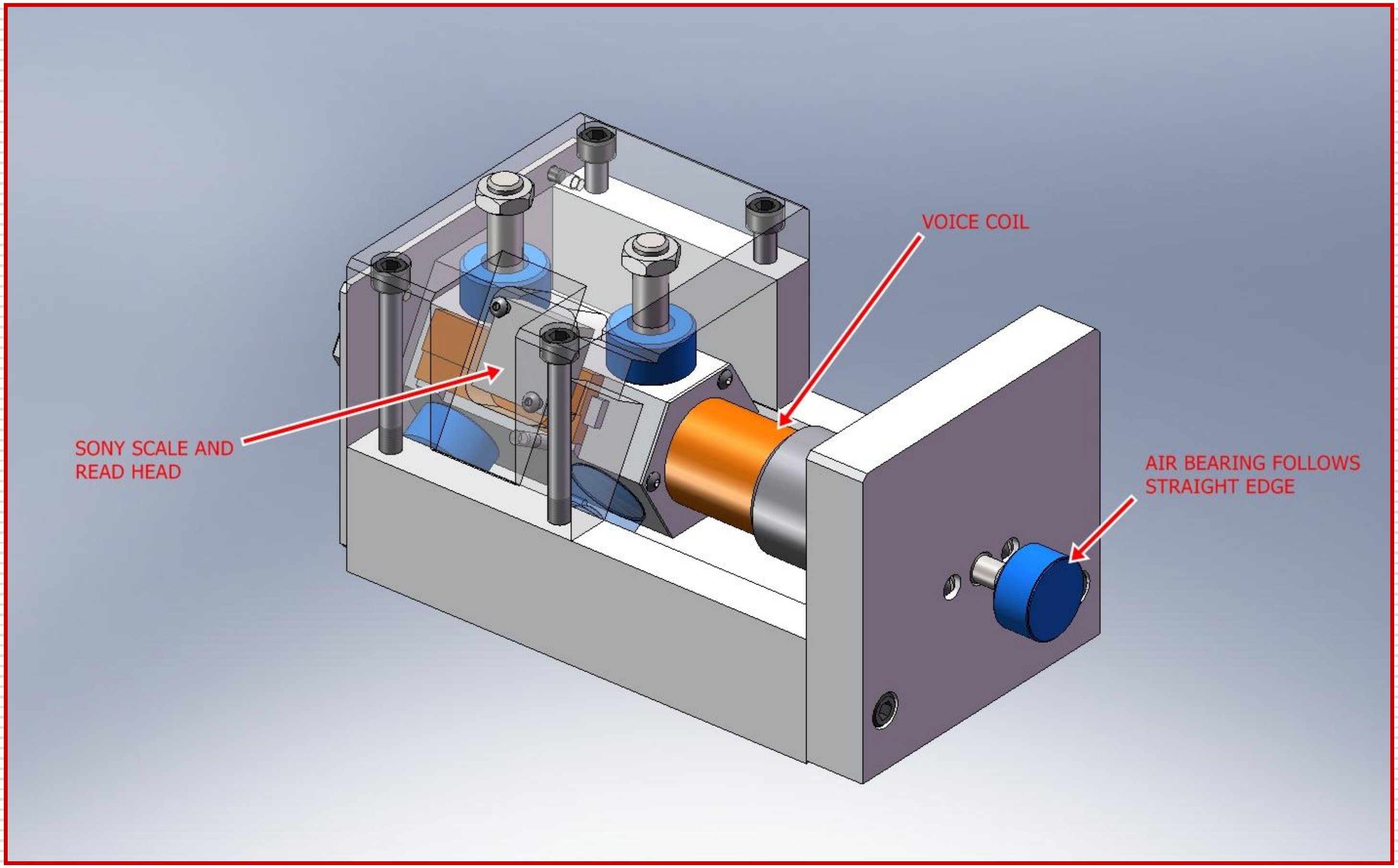
An overall perspective of the IXOMMM (without temperature enclosure)



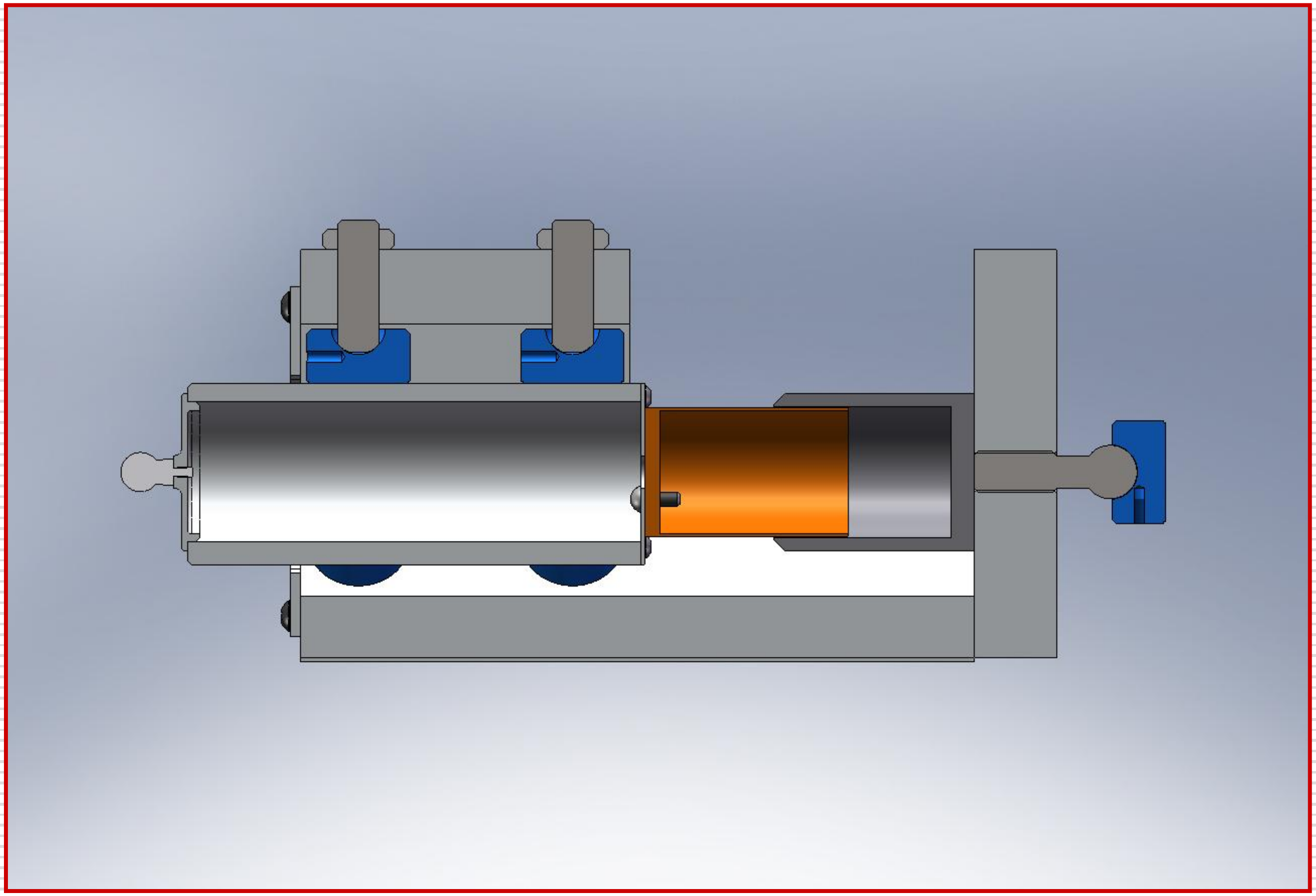
Axis nomenclature and critical components and details of the IXOMMM



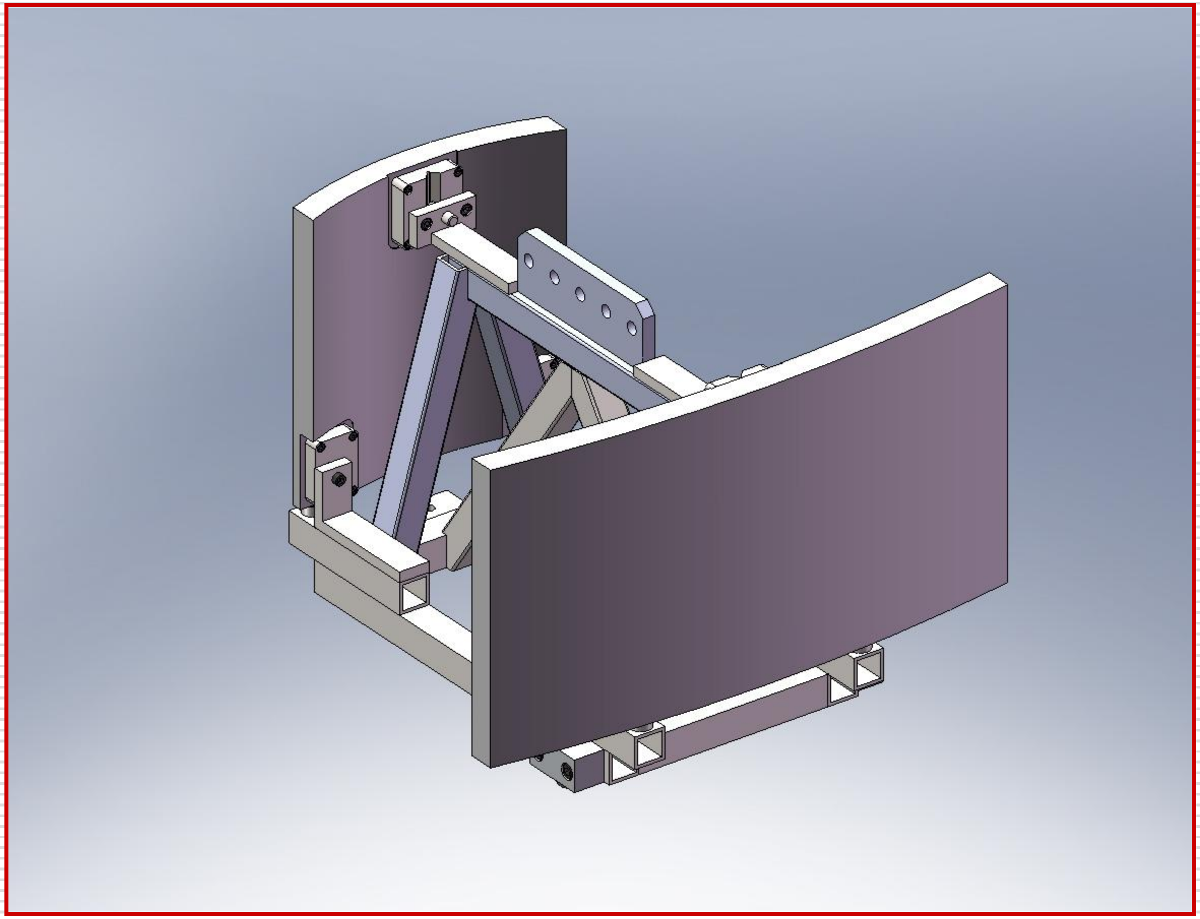
The gaugehead is actuated with a voice coil to provide a gauging range of 30 mm. Resolution is 53 pm, construction is principally Zerodur



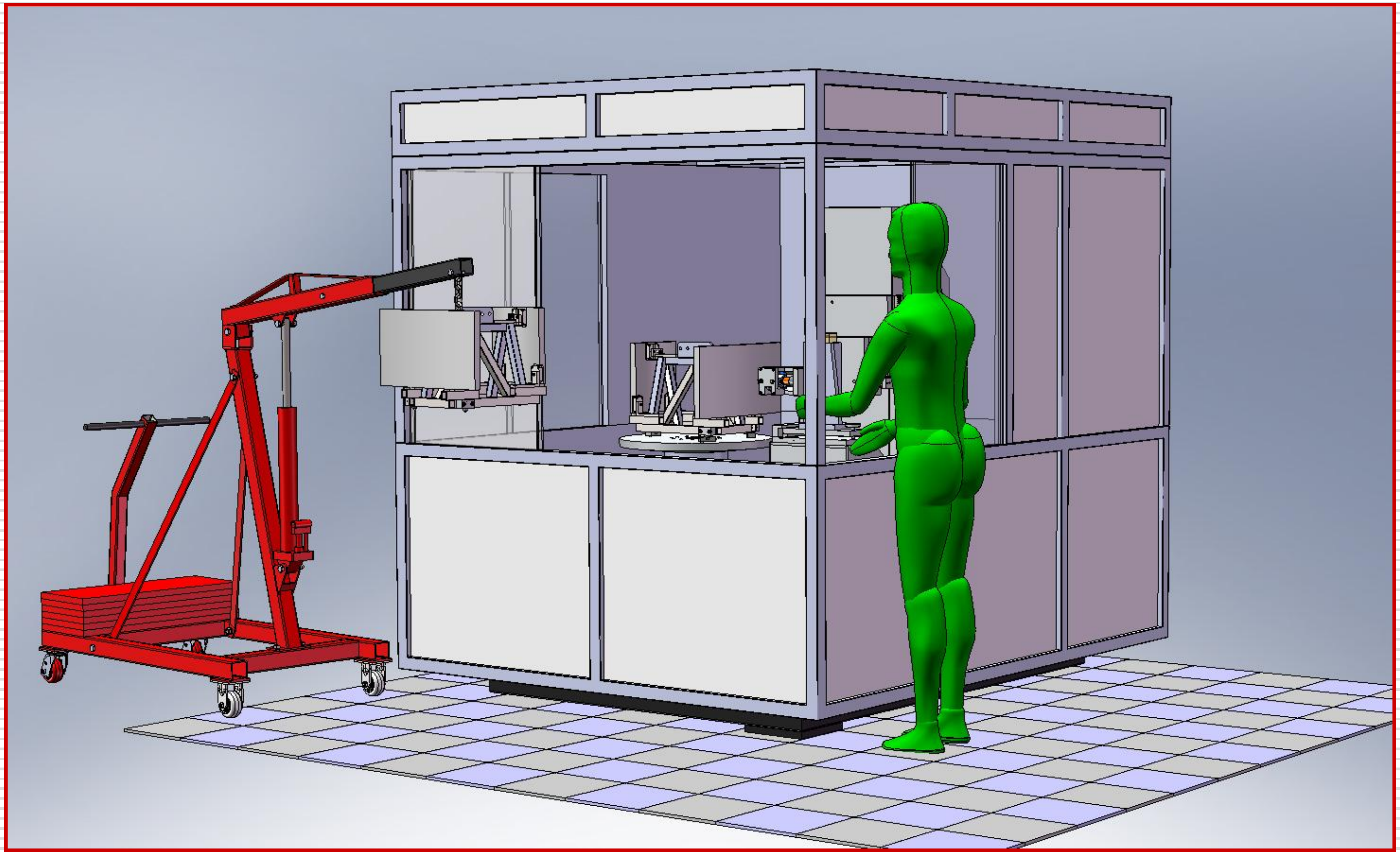
Section view of the gaugehead



Mandrel components are mounted kinematically to a frame, which is kinematically supported to the rotary table. The entire assembly can then be kinematically mounted on the polisher.



Temperature in the enclosure around the IXOMMM will be maintained within +/- 0.005^{0} C.



Summary of current project status, Phase I work remaining

- Conceptual design is 95% complete
- Error budget is in progress—and has been used as a tool to guide the design, materials selection
- Specification is complete, measuring process established
- Phase I work remaining: Completion of error budget, Final Report, Plan for Implementation (Phase II), Plan for integrating to polisher (Phase III)

Acknowledgements

We gratefully acknowledge the input of Peter Blake (COTR) and William Zhang. This work was supported by NASA SBIR S4.04-9574.